Space Weather Technical Forecast

Issued on Tuesday 31 December 2024 at 00:34 Local

This technical forecast provides a four-day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

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Space Weather Forecast Headline: R1/R2 Radio Blackouts expected throughout. Chance of R3 blackouts. A CME arrival is expected on 31 Dec, with G1-G2 Minor/Moderate storm likely, with a slight chance of G3 Strong storm.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: High, with a peak X1.5 flare observed from AR3936 at 30/0414 UTC with frequent M-class flares throughout. AR3932 in the southwest also produced an X1.1 flare, peaking at 30/0429UTC. There have been numerous M-class flares throughout the period. There has also been evidence of some flaring from beyond the eastern limb.

There are currently ten sunspot regions on the visible disc. AR3936 is the largest and most active region in the northwest quadrant, but has been relatively stable in terms of growth over the last 24 hours, with some grouping of the intermediate spots being shown in recent imagery. AR3939 continues to show minor growth in size with positive polarity spots surrounding negative spots in the centre and increasing leader spots. AR3938 appears to be stable, with little change in the magnetic configuration over the last 24 hours. AR3932 continues to fade with many of the spots weakening markedly. AR3941 is stable, with the region slowly spreading horizontally. The regions close to the western limb are difficult to diagnose and the remaining regions are all relatively simple or only slowly evolving.

Numerous CMEs have been observed leaving the disc on SOHO LASCO imagery over the past 24 hours. However, these mostly considered to have been far-sided in origin. A filament eruption and dimming event was observed on GONG H-alpha imagery in the vicinity of AR3939 at 29/0436 UTC, which produced a partial halo CME seen in LASCO and STEREO-A imagery. This event has been analysed and the results show an Earth-directed CME, which is expected to arrive at Earth on Day 1 (31 Dec).

Another partial halo emerged in LASCO imagery after 29/1800UTC, likely associated with AR3939 and likely having an Earth-directed element arriving on Day 2 (01 Jan). Although it appears to be rather faint compared to the previous event, with less material expected.

Solar Wind / Geomagnetic Activity: Solar winds, as observed at L1 by ACE remained at background levels throughout, between 330-360km/s. Density was mostly below average, with a very brief period of near average or slightly above average around 30/0500-0600 UTC. The Interplanetary Magnetic Field (IMF) was mainly weak through much of the period. The north-south

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component remained weak, initially positive but becoming erratic, ranging between -7nT and +7nT. Phi angle was mostly positive (away from the Sun). Quiet geomagnetic activity throughout (Kp 0-2).

Energetic Particles / Solar Radiation: High energy proton flux (greater than 10MeV) at GOES18 remained at background throughout, well below the S1/Minor Radiation Storm threshold.

High energy electron flux (greater than 2MeV) at GOES16 was at Background, diurnally peaking at Moderate levels, peaking at 30/2055 UTC at 164pfu. The associated 24-hour fluence was below the Active (1e8 integrated flux) threshold on a slightly declining trend. The 31/0001UTC observation was 3.21e6 integrated pfu.

Four-Day Space Weather Forecast Summary

Solar Activity: Moderate solar activity is expected with frequent M-class flares forecast through the period, with a chance of isolated X-class flares, especially from AR3936 in the northwest.

Solar Wind / Geomagnetic Activity: No coronal hole fast winds currently feature in the forecast. A partial halo CME observed in SOHO LASCO C2/C3 looks to be associated with an M2.0 flare and a filament eruption near the vicinity of AR3939 in the southeast quadrant at around 29/0440UTC a dimming was observed in GOES SUVI imagery. This event has been analysed, with an Earth-directed CME expected to arrive on day 1 (31 Dec). A second, slower partial halo CME was observed from AR3939 later on 29 Dec, with the potential to reach Earth on Day 2 (01 Jan), however little material is expected with this second CME.

Geomagnetic activity is expected to be mainly Quiet. The aforementioned Earth-directed CMEs arriving on days 1-2 (31 Dec - 01 Jan) are likely to enhance geomagnetic activity, reaching G1-G2 Minor/Moderate storm, with a slight chance of G3/Strong storm. Any CME effects gradually waning on day 3 (02 Jan), back towards Quiet to Unsettled conditions.

Energetic Particles / Solar Radiation: There is a slight chance of S1/Minor Radiation Storm enhancements during the period, should any significant flares occur from the larger regions on the disc as they rotate into the western hemisphere. Electron flux levels remain Background to Moderate but are expected to gradually ease into the period with enhanced geomagnetic activity. Electron fluence will most likely remain below the Active threshold.

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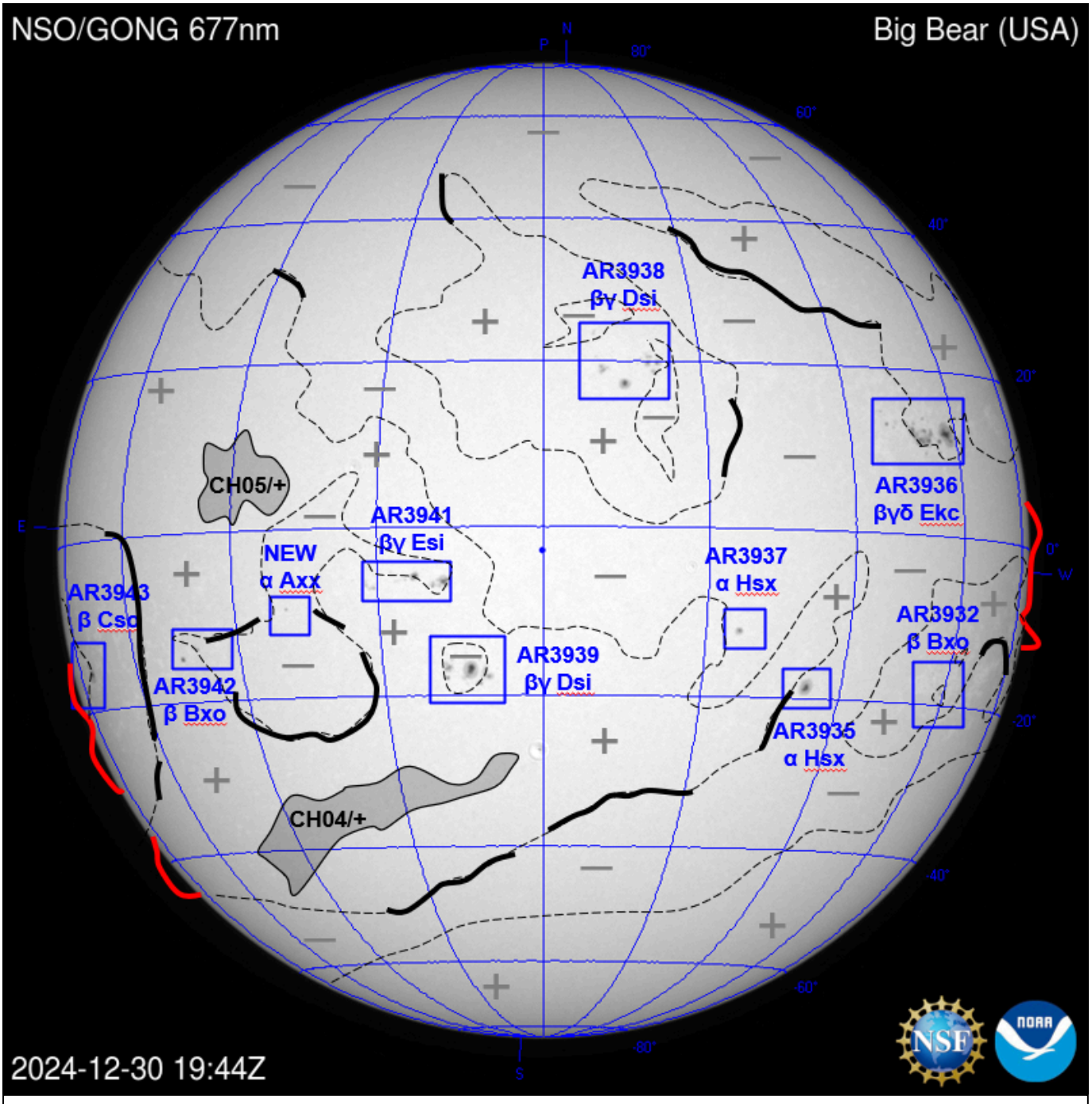
Figure 1: Solar analysis map - valid 30/1944UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms

A filament lift-off (following an M2 flare) from the southeast quadrant, close to AR3939 around 29/0436 UTC appears to have produced a fast partial halo CME, which has been analysed as Earth-directed, with an expected arrival on Day 1 (31 Dec) (estimated time of arrival 1500 UTC). A second partial halo CME was observed leaving the Sun later on the 29 Dec in association with a M3.3 flare from AR3939 in the southeast, this may bring some enhancement on Day 2 (01 Jan) although there does not appear to be much material associated with the shock. Following on from the X1.5 flare from AR3936 on 30/0414 UTC, some slow ejecta can be seen leaving the Sun at this time, although we are awaiting further analysis to decide if there are any Earth-directed elements.

Solar winds are otherwise are averaging around 330km/s and are expected to remain at background levels, before the arrival of the aforementioned CME on the 31 Dec, where solar winds could reach elevated to strong levels, between 500-700km/s.

Any fast wind enhancement from CH04+ is likely to be minimal given the proximity to the winter solstice and not until after the current forecast period.

The arrival of the anticipated partial halo CME, which left the Sun on the 29 Dec, shortly followed by the second partial halo CME is likely to enhance geomagnetic activity to G1-G2/Minor-Moderate storm levels, with a slight chance of reaching a G3/Strong storm interval on Days 1-2 (31 Dec - 01 Jan). Any CME effects gradually waning into Day 3 (02 Jan), back towards Quiet to Unsettled conditions, with isolated Active intervals.

Geomagnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	**G1 to G2**	No	60	60	20	5
Strong	**G3**	No	20	20	5	1
Severe	**G4**	No	1	1	1	1
Extreme	**G5**	No	1	1	1	1

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Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R⊙ (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed (km/s)	Estimated Arrival Time (UTC)	Comments
2024-12-29 (0955UTC)	Partial	Near AR3939	Southeast	1015km/s	2024-12-31 (1500UTC)	M2 flare and associated filament eruption near AR3939 produced a partial halo CME.
2024-12-29 (2310 UTC)	Partial	AR3939	Southeast	697 km/s	2025-01-01 (0900UTC)	

Figure 2: SOHO LASCO C3 difference imagery, showing the partial halo CME, which has been analysed as Earth-directed, arriving on Dec 31.

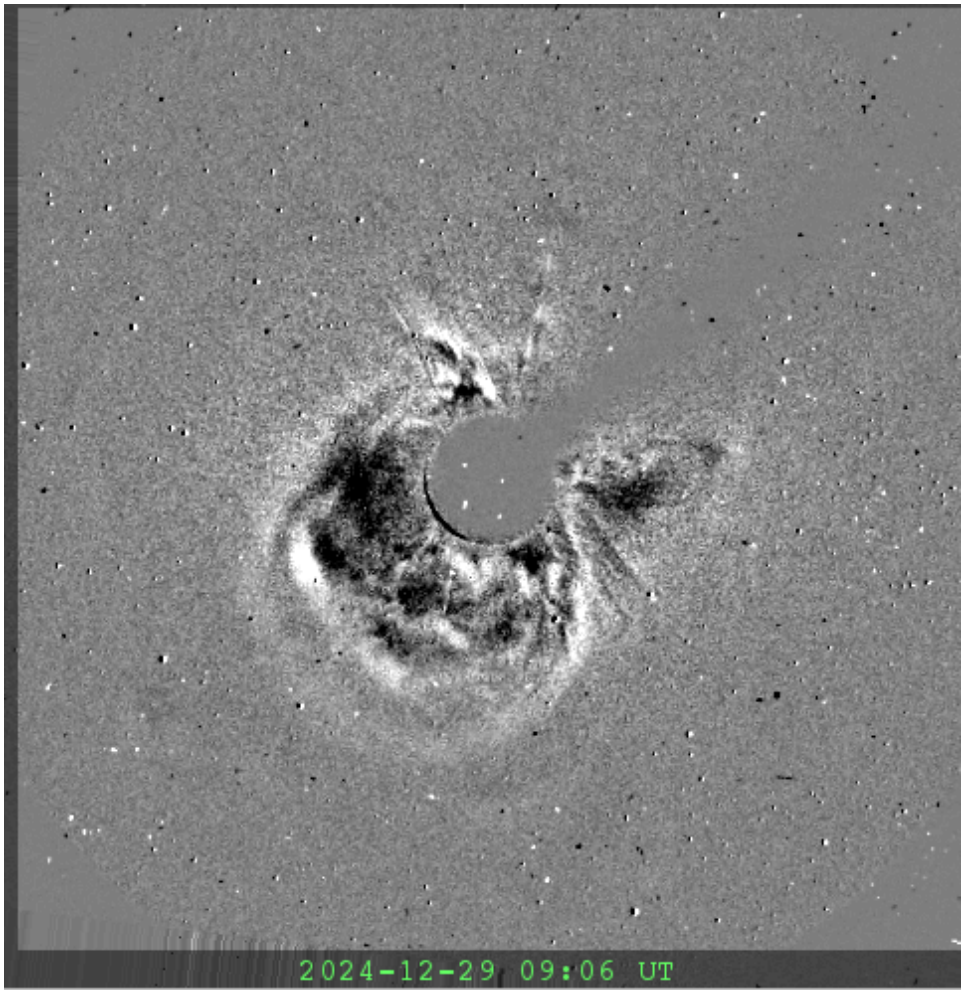

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Figure 3: MOSWOC Enlil - shows the arrival of two CMEs likely on 31 Dec and 1 Jan.

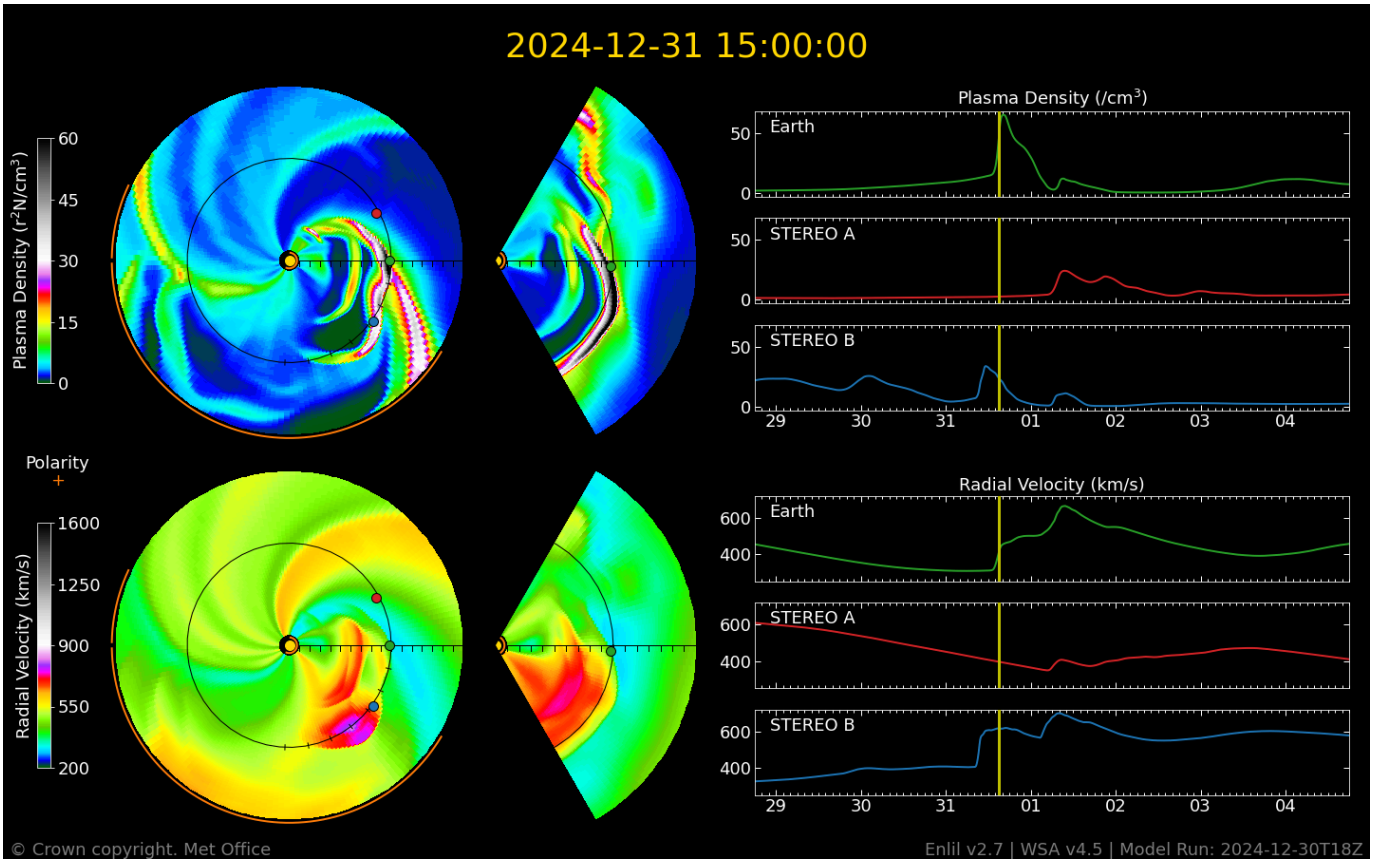

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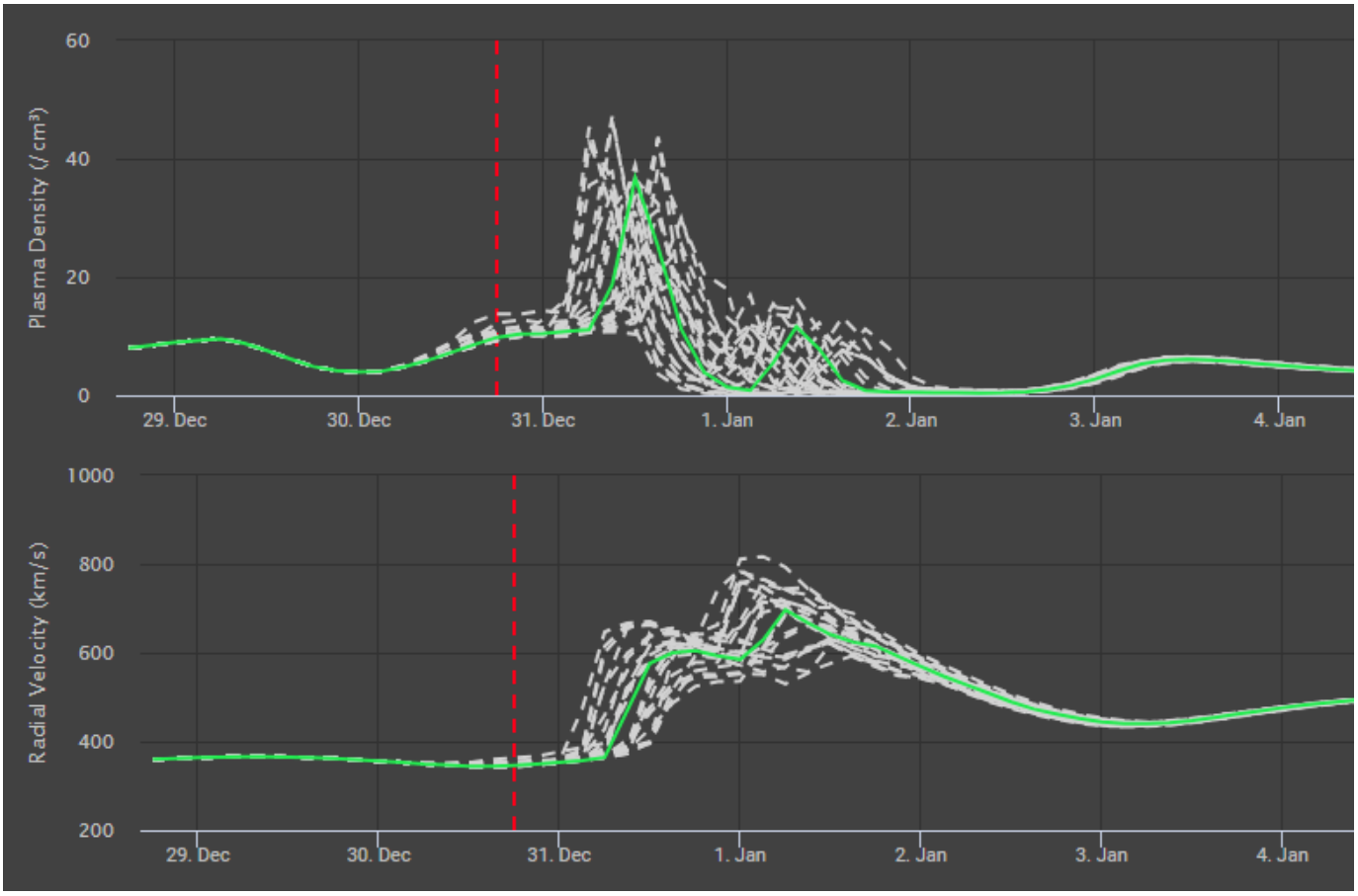
Figure 4: MOSWOC Enlil ensemble - shows some uncertainty in the arrival times of the two CMEs on 31 Dec and 1 Jan



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Radio Blackouts - X-Ray Flares

There are currently ten sunspot regions on the visible disc. AR3936 is the largest and most active region in the northwest quadrant, but has been relatively stable in terms of growth over the last 24 hours, with some grouping of the intermediate spots being shown in recent imagery. This region consists of a beta-gamma-delta configuration and produced the largest flare of the last 24 hours, peaking at X1.5 at 30/0414 UTC. Some slow ejecta can be seen leaving the Sun at this time, which has been analysed and shows the ejecta passing ahead of Earth's orbit.

Recent activity near the vicinity of AR3939 in the southeast associated with an M2.0 flare at 29/0436 UTC and a subsequent filament eruption, produced a partial halo CME. This event has been analysed as Earth-directed, with the CME expected to arrived at Earth during the second half of 31 Dec. A second partial halo CME was observed leaving the Sun later on the 29 Dec in association with a M3.3 flare from AR3939 in the southeast, this may bring some enhancement during the first half of 01 Jan. AR3939 is growing in size with positive polarity spots surrounding negative spots in the centre. AR3938 appears to be stable, with little change in the magnetic configuration over the last 24 hours. AR3932 continues to fade with many of the spots weakening markedly, although is still producing isolated M-class flares. AR3941 is showing signs of developing slowly, with the region spreading horizontally. The regions close to the western limb are difficult to diagnose and the remaining regions are all relatively simple or only slowly evolving.

Recurrence suggests the potential for further sunspot regions to round the eastern limb during the period, with this supported by recent far-side CME activity. Although far-side sounding output is not showing any significant regions (likely due to their proximity to the limb where soundings have a minimum ability to detect such regions) limb flux looping and coronagraph imagery suggests the presence of regions approaching the limb. None of the main flare-producing sunspot regions are expected to rotate off of the disc during the forecast period.

Frequent Moderate flares are forecast through the period, with a chance of isolated X-class flares, especially from AR3936.

X-Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 (M Class)	Yes	90	90	90	90
Very Active	R3-R5 (X Class)	Yes	30	30	30	30

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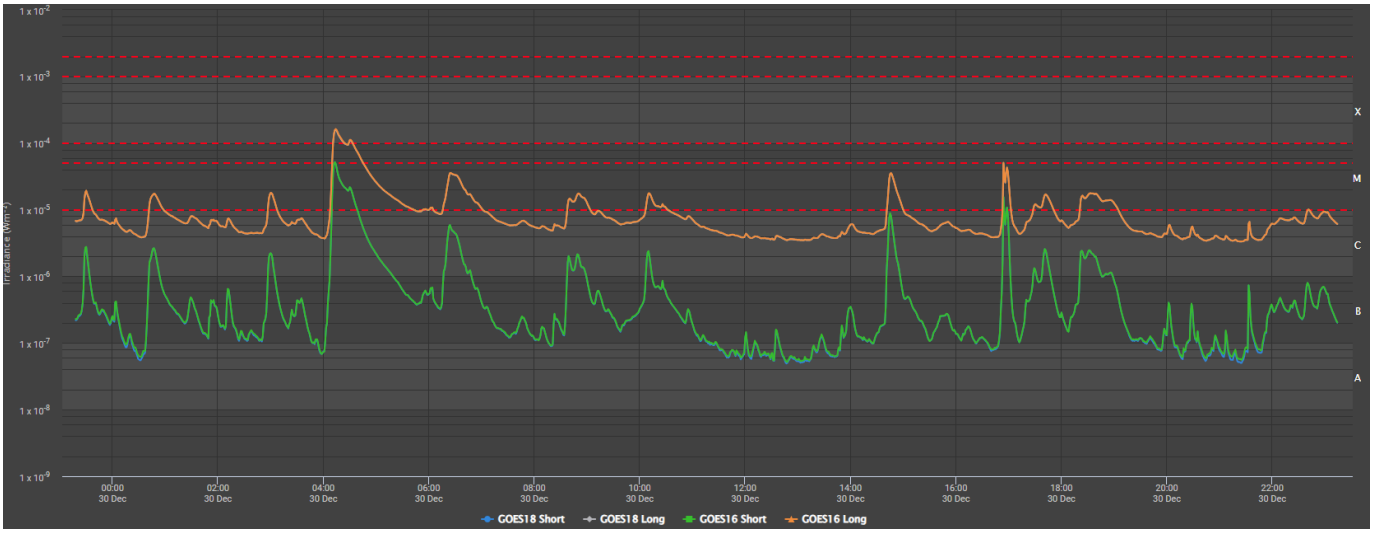
Figure 5: GOES16-18 X-Ray Flux



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Solar Radiation Storms (High Energy Protons)

High energy proton counts remain at Background values, with neither the X1.5 flare from AR3936 or the filament eruption from the southeast quadrant resulting in a noticeable increase in proton counts. There remains a slight chance of S1/Minor Solar Radiation storms should any significant flares occur from the larger regions on the disc as they rotate into more favourable locations for connection with Earth.

Radiation Storms Probability (Exceedance)	Level ($cm^{-2}sr^{-1}s^{-1}$)	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	No	15	15	15	15
Very Active	**≥ S3 ***	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and/or 50 MeV ≥ 10pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

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High Energy Electrons (≥ 2MeV)

High energy electron flux has remained at Background, with diurnal peaks up to Moderate levels in the last 24 hours. Electrons are likely to appear suppressed with the arrival of a CME on Day 1 (31 Dec) as the Van Allen belt becomes compressed away from the location of GEO. This may expand again after the current forecast period, seeing a rise in the electron levels. Electron fluence will most likely remain below the Active threshold throughout, as shown in MOSWOC REFM output, which is considered good guidance.

GEO Electron Environment	Level ($cm^{-2}sr^{-1}$ day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Active	≥ 2 MeV ≥ 1×10^{8}	No	5	5	5	5
Very Active	≥ 2 MeV ≥ 1×10^{9}	No	1	1	1	1

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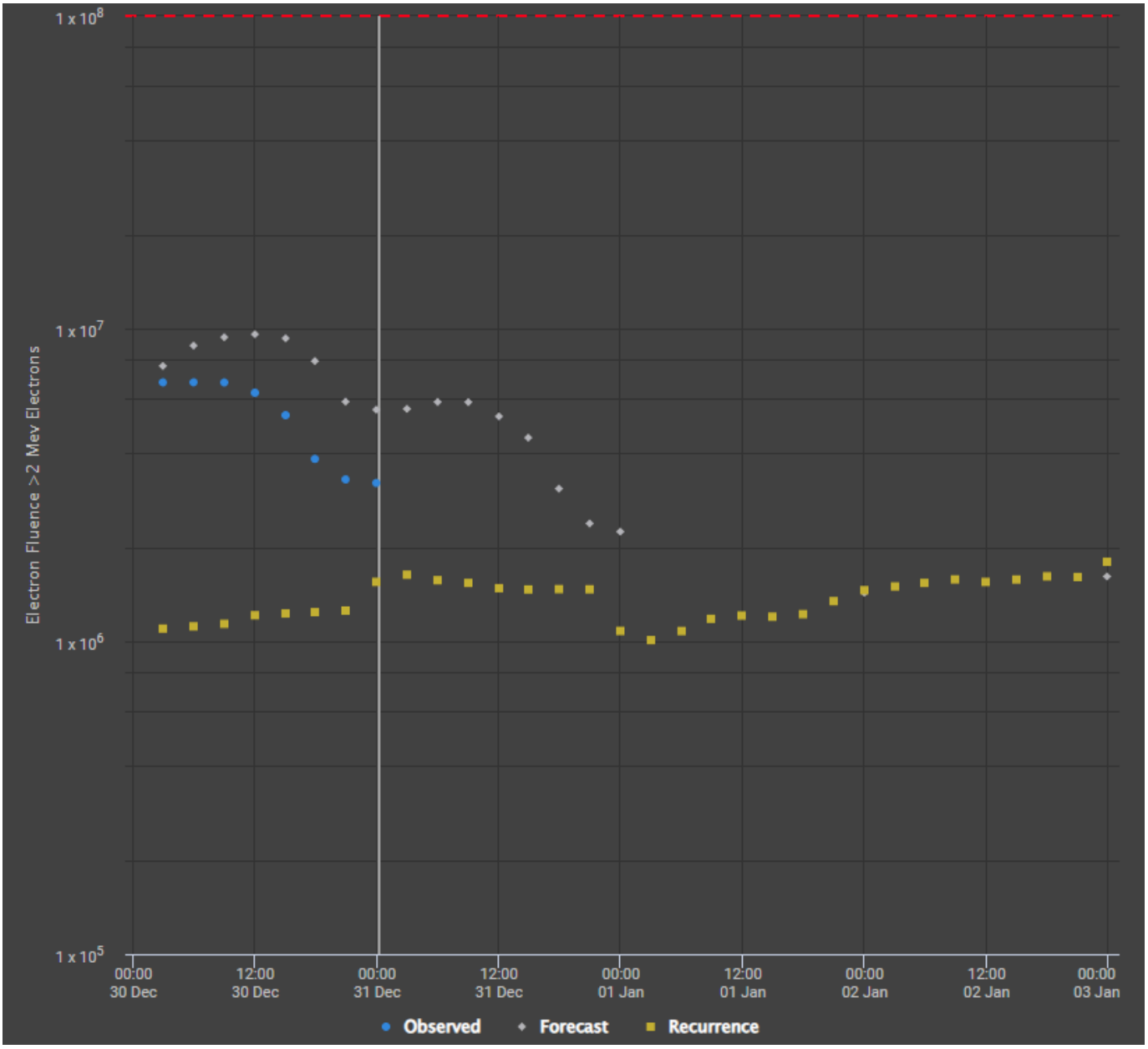
Figure 6: MOSWOC Electron fluence



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